Effective collision strengths between Mg I and electrons[*]
(Research Note)

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ABSTRACT

The treatment of the inelastic collisions with electrons and hydrogen atoms are the main source of uncertainties in non-Local Thermodynamic Equilibrium (LTE) spectral line computations. We report, in this research note, quantum mechanical data for 369 collisional transitions of Mg I with electrons for temperatures comprised between 500 and 20000 K. We give the quantum mechanical data in terms of effective collision strengths, more practical for non-LTE studies.

Key words. atomic data, atomic processes

1. Introduction

Atomic data are the main ingredient for a good non-local thermodynamic equilibrium (non-LTE) description of the interaction of a chemical species with matter and radiation in atmospheres of late-type stars. Huge efforts have been made over the years regarding experimental and theoretical data (see e.g. Henry 1993). Semi-classical or empirical formulæ are widely used because they provide rough estimates of collision rates based on oscillator strength for radiatively permitted transitions while no formulæ exist to correctly treat the forbidden transitions. The most used of such formulæ is the impact parameter method (IPM, Seaton 1962a,b) which implies computing collision cross-sections for weak and strong coupling. A simpler way (but also not as precise) is to use the semi-empirical formulation from van Regemorter (1962) which is an approximation of the IPM using experimental data available at that time. A more recent version that takes into account recent experimental data give a formulation with a dependance on the change of the principal quantum number (Fisher et al. 1996) but this version is not used very often in the literature.

Magnesium is an α-element produced by type II supernovæ of which is important to study its enrichment relative to iron in different stellar populations. The numerous optical lines of Mg I, including the green b triplet, allow the determination of its abundance in many kinds of stars which is why a good description of its atomic data and especially the inelastic collisions are needed. Zatsarinny et al. (2009) lead a very detailed study of angle-differential cross-sections for electron scattering from neutral magnesium using a B-spline R-matrix (BSR) method. However, only results for five collision cross-sections with the the ground state were published in this paper, whereas many collision cross-sections were computed. In the present research note, we decided to publish the other data in the form of effective collision strengths useful for non-LTE applications and which concern 369 transitions between excited states.

2. Previous calculations

In Zatsarinny et al. (2009), 37 target states were included in the scattering calculations. The configurations, terms, energy levels, and statistical weights g are given in Table 1. The Grotrian diagram of the energy levels are given in the top panel of Fig. 1. The double excited level $3p^2\ ^1S$ located above the ionization energy is also included owing to big mixing of this configuration to the ground state. This improves the convergence of the total scattering function. The quality of the model atom description can be assessed from the theoretical oscillator strengths they calculated compared with the NIST[1] counterparts. The differences are less than 3 %. Accurate oscillator strengths are important for subsequent calculations of collision cross-sections.

The B-spline R-matrix code (Zatsarinny 2006) was used for the scattering calculations. Angle-differential cross-sections for electron-impact excitation are obtained and described in detail in Zatsarinny et al. (2009). In their Fig. 8, they show angle-integrated cross-sections for five transitions with the ground state but cross-sections for 369 transitions were actually obtained and not published. Such cross-sections are extremely important for non-LTE studies. With 37 levels included, there are a total of 666 collision transition possibilities. We present here all the transitions between the first 17 levels up to $3s5p\ ^1P°$, and all effective collision strengths for excitation of these levels to the more excited level indicated in Table 1. There are 369 overall (see bottom panel of Fig. 1). Though the cross-section for transitions between highly-excited levels can also be extracted from the BSR calculation, they cannot be considered reliable because of slow partial wave convergence for these levels. In non-LTE calculations, we hardly need detailed cross-sections, but rather thermal average quantities such as effective collision strengths.

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[*] Quantum mechanical calculations from Zatsarinny et al. 2009, Phys. Rev. A., 79, 052709.

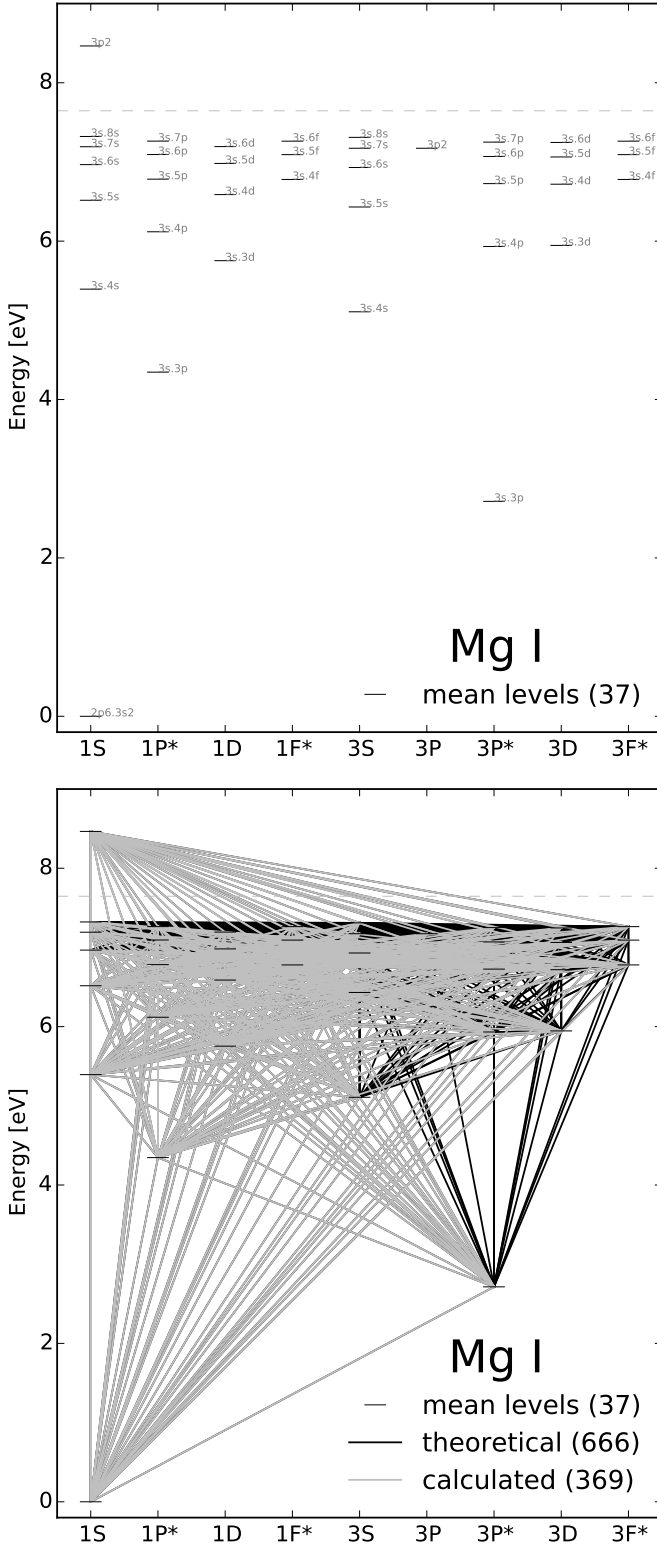[1] Available at: http://www.nist.gov/pml/data/asd.cfm

Fig. 1. Grotrian diagram of Mg I with mean energy levels labeled (top) and with the collision transitions (bottom). Theoretical collision transitions are shown with black lines whereas the calculated ones are shown with grey lines.

Table 1. Energy levels of Mg I.

Index	Conf.	Term	E [eV]	E [cm^{-1}]	g
1	3s^2	^{1}S	0.000	0.0000	1
2	3s3p	^{3}P°	2.645	21890.8541	9
3	3s3p	^{1}P°	4.286	35051.2640	3
4	3s4s	^{3}S	5.015	41197.4030	3
5	3s4s	^{1}S	5.301	43503.3330	1
6	3s3d	^{1}D	5.640	46403.0650	5
7	3s4p	^{3}P°	5.822	47847.7968	9
8	3s3d	^{3}D	5.834	47957.0416	15
9	3s4p	^{1}P°	6.018	49346.7290	3
10	3s5s	^{3}S	6.321	51872.5260	3
11	3s5s	^{1}S	6.407	52556.2060	1
12	3s4d	^{1}D	6.473	53134.6420	5
13	3s4d	^{3}D	6.603	54192.2845	15
14	3s5p	^{3}P°	6.611	54251.4108	9
15	3s4f	^{1}F°	6.660	54676.4380	7
16	3s4f	^{3}F°	6.660	54676.7130	21
17	3s5p	^{1}P°	6.671	54706.5360	3
18	3s6s	^{3}S	6.815	55891.8000	3
19	3s6s	^{1}S	6.852	56186.8730	1
20	3s5d	^{1}D	6.865	56308.3810	5
21	3s5d	^{3}D	6.946	56968.2386	15
22	3s6p	^{3}P°	6.952	57018.3750	9
23	3s5f	^{1}F°	6.973	57204.1630	7
24	3s5f	^{3}F°	6.973	57204.2740	21
25	3s6p	^{1}P°	6.978	57214.9920	3
26	3s7s	^{3}S	7.057	57855.2140	3
27	3s6d	^{1}D	7.078	58023.2460	5
28	3s7s	^{1}S	7.078	58009.4100	1
29	3p^2	^{3}P	7.081	57853.6300	9
30	3s6d	^{3}D	7.133	58442.8469	15
31	3s7p	^{3}P°	7.140	58477.3943	9
32	3s6f	^{3}F°	7.148	58575.5270	21
33	3s6f	^{1}F°	7.148	58575.4770	7
34	3s7p	^{1}P°	7.156	58580.2300	3
35	3s8s	^{3}S	7.225	58962.7390	3
36	3s8s	^{1}S	7.245	59053.5200	1
37	3p^2	^{1}S	8.476	68275.0000	1

3. Effective collision strengths

The collision rate from state i to state j with electrons C_{ij}^e can be written as

$$C_{ij}^e(T) = n_e \, \mathcal{A} \, \frac{\Upsilon_{ij}^e(T)}{g_i \sqrt{T}} e^{-E_{ij}/kT} \quad [\text{s}^{-1}] \tag{1}$$

where n_e is the electron density, g_i the statistical weight of the lower level, E_{ij} the transition energy, k the Boltzmann constant, T the temperature of the medium and $\mathcal{A}$ the constant

$$\mathcal{A} = \pi a_0^2 \left[\frac{8E_H^\infty}{\pi m_e}\right]^{1/2} \left[\frac{E_H^\infty}{k}\right]^{1/2} = 8.629 \times 10^{-6} [\text{cm}^3 \text{ s}^{-1} \text{ K}^{1/2}], \tag{2}$$

where a_0 is the Bohr radius, E_H^∞ is the Rydberg unit of energy, and m_e the mass of electron. Moreover, we use the effective collision strenght Υ_{ij}^e defined as

$$\Upsilon_{ij}^e = g_i \frac{kT}{E_H^\infty} \int_0^\infty \sigma_{ij}(x)(x + x_{ij}) e^{-x} dx \tag{3}$$

where $x = E/kT$ and $x_{ij} = E_{ij}/kT$ are the kinetic energy after excitation and the energy of the transition in unit of kT, σ_{ij} is the collision cross-section expressed in unit of πa_0^2, and Υ_{ij}^e is dimensionless and symmetric with respect to the transition (i.e.

$\Upsilon^e_{ij} = \Upsilon^e_{ji}$). The resulting effective collision strengths are given in Table 2[2] for nine temperatures between 500 and 20000 K. The level indexes in Table 2 refer to thr levels in Table 1.

These data will be useful for non-LTE studies of magnesium in stellar atmospheres of cool stars since they come from reliable quantum mechanical calculations. We should mention that such efforts toward calculating and collecting quantum mechanical data for inelastic collisions is extremely important so as to derive reliable non-LTE abundance corrections. Special efforts are also currently underway for computing inelastic collisions with hydrogen atoms (Barklem et al. 2011; Belyaev et al. 2014).

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[2] Table 2 available electronically only.

Table 2. Effective collision strengths.

Level index		Temperature [K]								
i	*j*	500	1000	2000	4000	6000	8000	10000	15000	20000
1	2	3.14e−02	9.78e−02	3.09e−01	9.00e−01	1.58e+00	2.28e+00	2.97e+00	4.59e+00	6.04e+00
1	3	1.63e−02	3.74e−02	9.64e−02	2.96e−01	5.98e−01	9.92e−01	1.47e+00	3.06e+00	5.21e+00
1	4	2.04e−03	6.55e−03	2.05e−02	5.69e−02	9.56e−02	1.33e−01	1.70e−01	2.54e−01	3.30e−01
1	5	6.92e−04	3.81e−03	1.62e−02	4.93e−02	8.54e−02	1.23e−01	1.62e−01	2.69e−01	3.91e−01
1	6	4.23e−03	1.20e−02	3.03e−02	7.26e−02	1.24e−01	1.85e−01	2.58e−01	4.95e−01	8.18e−01
1	7	8.56e−03	1.91e−02	4.15e−02	8.85e−02	1.35e−01	1.80e−01	2.23e−01	3.27e−01	4.27e−01
1	8	2.39e−03	6.95e−03	2.23e−02	6.82e−02	1.26e−01	1.92e−01	2.64e−01	4.67e−01	6.94e−01
1	9	2.72e−03	7.48e−03	2.09e−02	5.46e−02	9.59e−02	1.46e−01	2.08e−01	4.18e−01	7.16e−01
1	10	1.66e−03	4.70e−03	1.10e−02	2.23e−02	3.27e−02	4.27e−02	5.27e−02	7.82e−02	1.04e−01
1	11	1.89e−03	4.42e−03	9.35e−03	1.91e−02	2.95e−02	4.12e−02	5.45e−02	9.52e−02	1.46e−01
1	12	3.32e−03	7.56e−03	1.60e−02	3.25e−02	5.02e−02	7.03e−02	9.37e−02	1.66e−01	2.57e−01
1	13	2.94e−03	6.95e−03	1.55e−02	3.47e−02	5.72e−02	8.35e−02	1.14e−01	2.05e−01	3.12e−01
1	14	1.73e−03	4.00e−03	9.18e−03	2.09e−02	3.33e−02	4.62e−02	5.97e−02	9.55e−02	1.33e−01
1	15	1.59e−03	3.39e−03	6.70e−03	1.29e−02	1.89e−02	2.51e−02	3.14e−02	4.82e−02	6.65e−02
1	16	9.44e−04	2.49e−03	5.49e−03	1.12e−02	1.75e−02	2.45e−02	3.22e−02	5.29e−02	7.38e−02
1	17	1.16e−03	3.21e−03	8.00e−03	1.92e−02	3.29e−02	4.99e−02	7.10e−02	1.43e−01	2.43e−01
1	18	9.68e−04	2.06e−03	4.01e−03	7.79e−03	1.16e−02	1.57e−02	2.00e−02	3.16e−02	4.37e−02
1	19	6.46e−04	1.42e−03	3.05e−03	6.74e−03	1.11e−02	1.65e−02	2.28e−02	4.26e−02	6.68e−02
1	20	1.96e−03	4.51e−03	9.09e−03	1.78e−02	2.81e−02	4.05e−02	5.48e−02	9.64e−02	1.44e−01
1	21	1.30e−03	2.95e−03	6.38e−03	1.60e−02	3.07e−02	5.01e−02	7.31e−02	1.41e−01	2.18e−01
1	22	9.44e−04	2.31e−03	5.12e−03	1.15e−02	1.94e−02	2.90e−02	3.98e−02	6.99e−02	1.02e−01
1	23	1.17e−03	2.50e−03	5.05e−03	1.01e−02	1.59e−02	2.24e−02	2.95e−02	4.89e−02	6.93e−02
1	24	5.97e−04	1.42e−03	2.99e−03	6.69e−03	1.16e−02	1.74e−02	2.38e−02	4.08e−02	5.74e−02
1	25	7.72e−04	1.95e−03	4.40e−03	9.28e−03	1.47e−02	2.12e−02	2.92e−02	5.68e−02	9.54e−02
1	26	5.60e−04	1.22e−03	2.57e−03	5.00e−03	7.26e−03	9.53e−03	1.18e−02	1.76e−02	2.33e−02
1	27	1.68e−03	4.43e−03	1.17e−02	3.00e−02	5.01e−02	7.06e−02	9.12e−02	1.42e−01	1.91e−01
1	28	3.32e−04	8.13e−04	1.98e−03	4.54e−03	7.39e−03	1.07e−02	1.47e−02	2.66e−02	4.08e−02
1	29	6.47e−06	3.77e−05	2.27e−04	1.28e−03	3.20e−03	5.77e−03	8.81e−03	1.77e−02	2.77e−02
1	30	5.75e−04	1.65e−03	5.35e−03	1.88e−02	3.77e−02	5.98e−02	8.39e−02	1.48e−01	2.13e−01
1	31	6.79e−04	1.88e−03	5.63e−03	1.71e−02	3.25e−02	5.03e−02	6.91e−02	1.17e−01	1.61e−01
1	32	4.69e−04	1.16e−03	2.83e−03	7.06e−03	1.22e−02	1.79e−02	2.39e−02	3.91e−02	5.34e−02
1	33	4.44e−04	1.24e−03	3.77e−03	1.29e−02	2.63e−02	4.22e−02	5.95e−02	1.05e−01	1.52e−01
1	34	2.70e−04	6.98e−04	2.18e−03	8.36e−03	1.89e−02	3.32e−02	5.04e−02	1.04e−01	1.68e−01
1	35	1.14e−04	4.24e−04	2.05e−03	8.53e−03	1.64e−02	2.41e−02	3.13e−02	4.70e−02	6.07e−02
1	36	7.59e−05	1.97e−04	8.12e−04	4.11e−03	1.01e−02	1.84e−02	2.84e−02	5.85e−02	9.25e−02
1	37	5.77e−05	1.95e−04	6.33e−04	2.61e−03	6.54e−03	1.24e−02	1.98e−02	4.32e−02	7.12e−02
2	3	3.78e−02	8.45e−02	2.02e−01	5.43e−01	9.82e−01	1.47e+00	1.98e+00	3.26e+00	4.53e+00
2	4	4.88e−04	2.02e−03	8.64e−03	3.89e−02	9.75e−02	1.91e−01	3.24e−01	8.58e−01	1.70e+00
2	5	1.43e−02	3.87e−02	9.97e−02	2.32e−01	3.61e−01	4.82e−01	5.96e−01	8.53e−01	1.07e+00
2	6	2.55e−02	6.55e−02	1.56e−01	3.60e−01	5.91e−01	8.41e−01	1.11e+00	1.82e+00	2.60e+00
2	9	4.67e−03	1.71e−02	5.54e−02	1.48e−01	2.48e−01	3.53e−01	4.62e−01	7.44e−01	1.03e+00
2	11	8.44e−03	1.84e−02	3.90e−02	8.11e−02	1.23e−01	1.64e−01	2.05e−01	3.02e−01	3.93e−01
2	12	7.89e−03	1.76e−02	3.96e−02	9.14e−02	1.53e−01	2.25e−01	3.09e−01	5.61e−01	8.61e−01
2	15	1.65e−03	3.83e−03	8.99e−03	2.13e−02	3.61e−02	5.33e−02	7.26e−02	1.26e−01	1.82e−01
2	17	3.04e−03	8.84e−03	2.28e−02	5.60e−02	9.42e−02	1.36e−01	1.82e−01	3.03e−01	4.27e−01
2	19	2.58e−03	5.72e−03	1.28e−02	2.98e−02	4.89e−02	6.93e−02	9.05e−02	1.44e−01	1.97e−01
2	20	4.37e−03	1.02e−02	2.18e−02	4.74e−02	8.07e−02	1.23e−01	1.74e−01	3.29e−01	5.08e−01
2	23	1.33e−03	3.45e−03	7.95e−03	1.84e−02	3.15e−02	4.66e−02	6.29e−02	1.07e−01	1.51e−01
2	25	1.89e−03	4.78e−03	1.11e−02	2.54e−02	4.27e−02	6.29e−02	8.52e−02	1.45e−01	2.06e−01
2	27	3.07e−03	8.12e−03	2.18e−02	5.90e−02	1.05e−01	1.56e−01	2.11e−01	3.52e−01	4.95e−01
2	28	1.38e−03	3.20e−03	7.72e−03	1.78e−02	2.85e−02	4.01e−02	5.25e−02	8.50e−02	1.17e−01
2	33	1.23e−03	2.91e−03	7.61e−03	2.37e−02	4.64e−02	7.31e−02	1.02e−01	1.81e−01	2.60e−01
2	34	8.64e−04	2.22e−03	7.19e−03	2.76e−02	5.85e−02	9.53e−02	1.35e−01	2.35e−01	3.32e−01
2	36	3.27e−04	9.68e−04	3.88e−03	1.66e−02	3.57e−02	5.87e−02	8.37e−02	1.49e−01	2.13e−01
2	37	3.43e−04	1.35e−03	5.03e−03	1.85e−02	3.93e−02	6.62e−02	9.79e−02	1.91e−01	2.94e−01
3	4	3.69e−02	9.94e−02	2.63e−01	6.29e−01	9.79e−01	1.29e+00	1.58e+00	2.19e+00	2.70e+00
3	5	7.19e−02	2.22e−01	6.32e−01	1.64e+00	2.86e+00	4.33e+00	6.06e+00	1.15e+01	1.85e+01
3	6	7.52e−02	1.95e−01	4.73e−01	1.20e+00	2.15e+00	3.33e+00	4.73e+00	9.20e+00	1.50e+01
3	7	8.06e−02	1.89e−01	4.25e−01	9.23e−01	1.41e+00	1.88e+00	2.31e+00	3.27e+00	4.08e+00
3	8	2.78e−02	7.61e−02	2.11e−01	5.53e−01	9.31e−01	1.32e+00	1.71e+00	2.67e+00	3.63e+00
3	9	2.42e−02	6.92e−02	2.05e−01	5.77e−01	1.04e+00	1.58e+00	2.20e+00	4.14e+00	6.61e+00
3	10	6.62e−03	1.78e−02	4.37e−02	1.01e−01	1.59e−01	2.16e−01	2.70e−01	3.96e−01	5.09e−01
3	11	1.26e−02	2.73e−02	5.67e−02	1.16e−01	1.78e−01	2.48e−01	3.30e−01	5.93e−01	9.46e−01
3	12	2.42e−02	6.16e−02	1.48e−01	3.44e−01	5.60e−01	7.94e−01	1.05e+00	1.74e+00	2.53e+00
3	13	1.83e−02	4.43e−02	1.03e−01	2.23e−01	3.40e−01	4.56e−01	5.73e−01	8.71e−01	1.17e+00
3	14	9.96e−03	2.48e−02	5.82e−02	1.32e−01	2.09e−01	2.86e−01	3.62e−01	5.48e−01	7.27e−01
3	15	9.85e−03	3.01e−02	8.42e−02	2.30e−01	4.26e−01	6.74e−01	9.75e−01	1.94e+00	3.17e+00
3	16	1.06e−02	2.14e−02	4.35e−02	8.92e−02	1.41e−01	2.00e−01	2.66e−01	4.48e−01	6.33e−01
3	17	1.06e−02	2.96e−02	7.25e−02	1.64e−01	2.68e−01	3.91e−01	5.34e−01	9.89e−01	1.57e+00
3	18	2.68e−03	7.25e−03	1.71e−02	3.87e−02	6.11e−02	8.33e−02	1.05e−01	1.55e−01	2.00e−01
3	19	4.21e−03	1.03e−02	2.26e−02	4.64e−02	7.20e−02	1.02e−01	1.38e−01	2.53e−01	4.02e−01
3	20	1.16e−02	2.83e−02	6.32e−02	1.46e−01	2.52e−01	3.79e−01	5.24e−01	9.65e−01	1.51e+00
3	21	6.81e−03	1.80e−02	4.36e−02	1.04e−01	1.75e−01	2.53e−01	3.35e−01	5.44e−01	7.49e−01

Table 2. Continued.

Level index		Temperature [K]								
i	j	500	1000	2000	4000	6000	8000	10000	15000	20000
3	22	5.03e−03	1.32e−02	3.04e−02	6.81e−02	1.14e−01	1.67e−01	2.25e−01	3.80e−01	5.35e−01
3	23	8.71e−03	2.32e−02	5.44e−02	1.35e−01	2.52e−01	4.10e−01	6.07e−01	1.24e+00	2.03e+00
3	24	3.64e−03	1.02e−02	2.52e−02	5.99e−02	1.02e−01	1.50e−01	2.00e−01	3.28e−01	4.48e−01
3	25	7.00e−03	1.78e−02	4.00e−02	8.69e−02	1.45e−01	2.16e−01	2.99e−01	5.50e−01	8.47e−01
3	26	1.99e−03	4.96e−03	1.15e−02	2.38e−02	3.48e−02	4.50e−02	5.46e−02	7.62e−02	9.54e−02
3	27	8.73e−03	2.38e−02	6.74e−02	1.90e−01	3.34e−01	4.91e−01	6.57e−01	1.11e+00	1.62e+00
3	28	2.92e−03	7.27e−03	1.70e−02	3.57e−02	5.41e−02	7.47e−02	9.87e−02	1.75e−01	2.72e−01
3	29	9.04e−05	5.21e−04	3.04e−03	1.66e−02	4.17e−02	7.71e−02	1.21e−01	2.63e−01	4.40e−01
3	30	3.80e−03	1.21e−02	3.86e−02	1.12e−01	1.97e−01	2.82e−01	3.66e−01	5.62e−01	7.37e−01
3	31	3.27e−03	9.64e−03	2.84e−02	8.45e−02	1.58e−01	2.39e−01	3.23e−01	5.32e−01	7.25e−01
3	32	3.10e−03	9.18e−03	2.68e−02	6.95e−02	1.14e−01	1.56e−01	1.97e−01	2.90e−01	3.70e−01
3	33	2.91e−03	8.85e−03	3.23e−02	1.29e−01	2.88e−01	4.99e−01	7.53e−01	1.53e+00	2.44e+00
3	34	2.20e−03	6.47e−03	2.23e−02	8.90e−02	1.98e−01	3.38e−01	5.02e−01	9.82e−01	1.53e+00
3	35	8.28e−04	2.25e−03	6.94e−03	2.38e−02	4.57e−02	6.88e−02	9.18e−02	1.46e−01	1.95e−01
3	36	7.02e−04	2.30e−03	8.66e−03	3.21e−02	6.83e−02	1.17e−01	1.77e−01	3.64e−01	5.87e−01
3	37	4.85e−04	1.77e−03	7.92e−03	4.61e−02	1.38e−01	2.95e−01	5.20e−01	1.38e+00	2.62e+00
4	5	1.37e−02	2.85e−02	6.84e−02	1.89e−01	3.36e−01	4.92e−01	6.52e−01	1.06e+00	1.46e+00
4	6	1.12e−01	2.76e−01	6.33e−01	1.35e+00	1.99e+00	2.56e+00	3.07e+00	4.13e+00	5.00e+00
4	9	7.29e−03	2.34e−02	7.23e−02	1.92e−01	3.14e−01	4.31e−01	5.45e−01	8.19e−01	1.08e+00
4	11	3.75e−03	1.03e−02	2.83e−02	6.63e−02	1.00e−01	1.30e−01	1.56e−01	2.12e−01	2.60e−01
4	12	1.84e−02	4.22e−02	9.38e−02	2.02e−01	3.11e−01	4.21e−01	5.30e−01	7.89e−01	1.03e+00
4	15	1.10e−02	2.48e−02	5.71e−02	1.36e−01	2.24e−01	3.15e−01	4.06e−01	6.30e−01	8.36e−01
4	17	3.39e−03	1.02e−02	2.62e−02	5.61e−02	8.37e−02	1.11e−01	1.37e−01	2.05e−01	2.71e−01
4	19	3.46e−03	8.55e−03	1.81e−02	3.33e−02	4.50e−02	5.48e−02	6.34e−02	8.23e−02	9.90e−02
4	20	6.93e−03	1.77e−02	4.10e−02	9.30e−02	1.53e−01	2.18e−01	2.84e−01	4.40e−01	5.81e−01
4	23	5.85e−03	1.35e−02	3.07e−02	7.42e−02	1.28e−01	1.88e−01	2.50e−01	3.99e−01	5.34e−01
4	25	2.90e−03	7.92e−03	1.88e−02	4.00e−02	5.96e−02	7.79e−02	9.52e−02	1.35e−01	1.72e−01
4	27	5.25e−03	1.49e−02	4.33e−02	1.17e−01	1.93e−01	2.64e−01	3.29e−01	4.64e−01	5.72e−01
4	28	2.43e−03	5.50e−03	1.13e−02	2.06e−02	2.76e−02	3.34e−02	3.85e−02	5.00e−02	6.06e−02
4	33	2.86e−03	8.27e−03	2.65e−02	8.32e−02	1.50e−01	2.19e−01	2.85e−01	4.35e−01	5.61e−01
4	34	1.58e−03	4.69e−03	1.37e−02	3.53e−02	5.73e−02	7.80e−02	9.74e−02	1.41e−01	1.81e−01
4	36	6.88e−04	1.71e−03	4.44e−03	1.19e−02	2.06e−02	3.01e−02	3.98e−02	6.52e−02	9.06e−02
4	37	7.14e−05	4.19e−04	1.94e−03	6.23e−03	1.09e−02	1.55e−02	2.01e−02	3.10e−02	4.09e−02
5	6	2.91e−02	6.62e−02	1.64e−01	4.61e−01	8.76e−01	1.39e+00	1.98e+00	3.82e+00	6.17e+00
5	7	1.15e−01	2.48e−01	4.82e−01	8.39e−01	1.11e+00	1.32e+00	1.51e+00	1.92e+00	2.27e+00
5	8	2.95e−02	7.14e−02	1.93e−01	5.09e−01	8.35e−01	1.14e+00	1.43e+00	2.06e+00	2.62e+00
5	9	1.58e−02	6.98e−02	3.62e−01	1.63e+00	3.75e+00	6.71e+00	1.05e+01	2.38e+01	4.26e+01
5	10	2.91e−03	1.03e−02	3.10e−02	7.41e−02	1.13e−01	1.46e−01	1.76e−01	2.43e−01	3.01e−01
5	11	1.69e−02	4.30e−02	1.01e−01	2.21e−01	3.44e−01	4.79e−01	6.34e−01	1.14e+00	1.87e+00
5	12	2.72e−02	8.21e−02	2.35e−01	6.55e−01	1.21e+00	1.91e+00	2.78e+00	5.71e+00	9.64e+00
5	13	2.73e−02	5.83e−02	1.24e−01	2.54e−01	3.71e−01	4.76e−01	5.71e−01	7.74e−01	9.42e−01
5	14	1.38e−02	3.55e−02	7.92e−02	1.50e−01	2.06e−01	2.54e−01	2.97e−01	3.94e−01	4.81e−01
5	15	1.62e−02	4.69e−02	1.34e−01	4.39e−01	9.63e−01	1.71e+00	2.64e+00	5.64e+00	9.30e+00
5	16	8.17e−03	2.13e−02	6.02e−02	1.70e−01	2.96e−01	4.28e−01	5.58e−01	8.68e−01	1.14e+00
5	17	7.88e−03	2.82e−02	8.06e−02	2.02e−01	3.43e−01	5.13e−01	7.17e−01	1.40e+00	2.35e+00
5	18	1.93e−03	6.24e−03	1.47e−02	2.89e−02	4.10e−02	5.17e−02	6.15e−02	8.38e−02	1.04e−01
5	19	6.65e−03	1.57e−02	3.55e−02	7.82e−02	1.26e−01	1.80e−01	2.45e−01	4.57e−01	7.43e−01
5	20	9.56e−03	2.76e−02	6.66e−02	1.52e−01	2.62e−01	4.03e−01	5.75e−01	1.14e+00	1.89e+00
5	21	8.22e−03	2.05e−02	4.72e−02	1.06e−01	1.67e−01	2.28e−01	2.86e−01	4.17e−01	5.27e−01
5	22	6.70e−03	1.67e−02	3.53e−02	6.46e−02	8.95e−02	1.13e−01	1.37e−01	1.96e−01	2.52e−01
5	23	8.23e−03	2.11e−02	5.44e−02	1.58e−01	3.11e−01	5.08e−01	7.40e−01	1.44e+00	2.25e+00
5	24	3.32e−03	9.98e−03	2.72e−02	7.78e−02	1.45e−01	2.18e−01	2.92e−01	4.68e−01	6.22e−01
5	25	7.17e−03	1.90e−02	4.21e−02	8.53e−02	1.38e−01	2.09e−01	3.02e−01	6.27e−01	1.06e+00
5	26	2.63e−03	7.31e−03	1.67e−02	3.19e−02	4.30e−02	5.16e−02	5.88e−02	7.33e−02	8.50e−02
5	27	5.61e−03	1.66e−02	4.97e−02	1.42e−01	2.52e−01	3.69e−01	4.93e−01	8.20e−01	1.17e+00
5	28	3.82e−03	1.03e−02	2.66e−02	6.14e−02	9.67e−02	1.36e−01	1.80e−01	3.17e−01	4.93e−01
5	29	6.96e−06	4.24e−05	2.61e−04	1.65e−03	4.86e−03	1.03e−02	1.80e−02	4.59e−02	8.32e−02
5	30	4.40e−03	1.37e−02	4.20e−02	1.14e−01	1.86e−01	2.53e−01	3.13e−01	4.39e−01	5.38e−01
5	31	3.19e−03	8.75e−03	2.32e−02	5.74e−02	9.32e−02	1.29e−01	1.63e−01	2.41e−01	3.10e−01
5	32	3.61e−03	1.06e−02	3.22e−02	9.49e−02	1.64e−01	2.30e−01	2.92e−01	4.23e−01	5.29e−01
5	33	3.59e−03	1.01e−02	2.96e−02	9.21e−02	1.80e−01	2.87e−01	4.07e−01	7.50e−01	1.13e+00
5	34	2.20e−03	6.96e−03	2.80e−02	1.17e−01	2.59e−01	4.38e−01	6.45e−01	1.24e+00	1.89e+00
5	35	8.19e−04	2.16e−03	5.00e−03	1.17e−02	1.97e−02	2.83e−02	3.71e−02	5.87e−02	7.89e−02
5	36	1.00e−03	2.97e−03	1.01e−02	3.61e−02	7.75e−02	1.33e−01	2.01e−01	4.12e−01	6.65e−01
5	37	5.14e−04	1.79e−03	5.48e−03	1.69e−02	3.52e−02	6.05e−02	9.24e−02	1.94e−01	3.17e−01
6	7	6.76e−02	1.77e−01	4.98e−01	1.38e+00	2.35e+00	3.30e+00	4.19e+00	6.21e+00	7.96e+00
6	8	3.52e−02	1.19e−01	4.14e−01	1.33e+00	2.46e+00	3.69e+00	4.98e+00	8.34e+00	1.17e+01
6	9	6.19e−02	2.97e−01	1.29e+00	4.92e+00	1.04e+01	1.77e+01	2.65e+01	5.48e+01	9.13e+01
6	10	4.77e−03	1.82e−02	6.18e−02	1.73e−01	2.90e−01	4.06e−01	5.18e−01	7.80e−01	1.01e+00
6	11	9.99e−02	2.60e−01	6.27e−01	1.46e+00	2.38e+00	3.36e+00	4.40e+00	7.19e+00	1.02e+01
6	12	1.02e−01	3.09e−01	8.65e−01	2.36e+00	4.36e+00	6.88e+00	9.94e+00	1.98e+01	3.24e+01
6	13	5.16e−02	1.22e−01	2.76e−01	6.01e−01	9.25e−01	1.24e+00	1.55e+00	2.28e+00	2.95e+00
6	14	2.33e−02	5.83e−02	1.49e−01	3.50e−01	5.41e−01	7.17e−01	8.80e−01	1.25e+00	1.56e+00

Table 2. Continued.

Level index		Temperature [K]								
i	*j*	500	1000	2000	4000	6000	8000	10000	15000	20000
6	15	5.71e−02	1.62e−01	4.60e−01	1.45e+00	3.08e+00	5.45e+00	8.61e+00	2.01e+01	3.65e+01
6	16	2.01e−02	5.05e−02	1.40e−01	3.90e−01	6.96e−01	1.04e+00	1.40e+00	2.32e+00	3.21e+00
6	17	2.32e−02	8.25e−02	2.49e−01	6.79e−01	1.20e+00	1.80e+00	2.47e+00	4.43e+00	6.75e+00
6	18	5.67e−03	1.80e−02	4.50e−02	9.69e−02	1.46e−01	1.93e−01	2.38e−01	3.41e−01	4.30e−01
6	19	2.15e−02	5.30e−02	1.18e−01	2.58e−01	4.20e−01	6.06e−01	8.14e−01	1.41e+00	2.06e+00
6	20	4.29e−02	1.18e−01	3.01e−01	8.36e−01	1.62e+00	2.64e+00	3.84e+00	7.47e+00	1.17e+01
6	21	2.01e−02	5.16e−02	1.17e−01	2.63e−01	4.34e−01	6.17e−01	8.03e−01	1.26e+00	1.68e+00
6	22	1.06e−02	2.76e−02	6.46e−02	1.43e−01	2.30e−01	3.23e−01	4.19e−01	6.58e−01	8.81e−01
6	23	2.66e−02	7.30e−02	1.88e−01	5.38e−01	1.10e+00	1.90e+00	2.94e+00	6.60e+00	1.16e+01
6	24	1.10e−02	3.09e−02	8.10e−02	2.10e−01	3.71e−01	5.49e−01	7.33e−01	1.19e+00	1.61e+00
6	25	1.38e−02	4.34e−02	1.19e−01	2.97e−01	5.09e−01	7.55e−01	1.03e+00	1.82e+00	2.73e+00
6	26	5.83e−03	1.67e−02	4.16e−02	8.85e−02	1.27e−01	1.61e−01	1.90e−01	2.49e−01	2.97e−01
6	27	2.05e−02	6.53e−02	2.21e−01	7.26e−01	1.38e+00	2.12e+00	2.89e+00	4.92e+00	6.97e+00
6	28	8.81e−03	2.61e−02	6.84e−02	1.55e−01	2.45e−01	3.44e−01	4.54e−01	7.60e−01	1.09e+00
6	29	3.83e−05	2.30e−04	1.43e−03	8.48e−03	2.25e−02	4.29e−02	6.90e−02	1.54e−01	2.60e−01
6	30	1.20e−02	3.67e−02	1.11e−01	3.04e−01	5.12e−01	7.15e−01	9.07e−01	1.34e+00	1.70e+00
6	31	7.67e−03	2.20e−02	6.27e−02	1.75e−01	3.09e−01	4.49e−01	5.86e−01	9.04e−01	1.18e+00
6	32	9.56e−03	2.81e−02	8.63e−02	2.43e−01	4.08e−01	5.64e−01	7.10e−01	1.03e+00	1.30e+00
6	33	1.48e−02	4.11e−02	1.29e−01	4.72e−01	1.02e+00	1.76e+00	2.67e+00	5.54e+00	9.16e+00
6	34	5.76e−03	2.00e−02	7.70e−02	2.95e−01	6.12e−01	9.90e−01	1.41e+00	2.58e+00	3.85e+00
6	35	1.76e−03	4.98e−03	1.46e−02	4.89e−02	9.65e−02	1.48e−01	1.99e−01	3.16e−01	4.16e−01
6	36	1.99e−03	5.91e−03	2.06e−02	7.83e−02	1.66e−01	2.78e−01	4.14e−01	8.42e−01	1.36e+00
6	37	7.19e−04	2.80e−03	1.01e−02	3.57e−02	7.64e−02	1.31e−01	1.98e−01	4.07e−01	6.59e−01
7	9	2.04e−02	6.32e−02	1.97e−01	5.71e−01	1.01e+00	1.50e+00	2.01e+00	3.35e+00	4.69e+00
7	11	1.48e−02	3.51e−02	7.96e−02	1.69e−01	2.58e−01	3.46e−01	4.33e−01	6.38e−01	8.24e−01
7	12	7.97e−02	1.90e−01	4.24e−01	8.96e−01	1.35e+00	1.78e+00	2.20e+00	3.14e+00	3.97e+00
7	15	3.01e−02	8.15e−02	2.09e−01	5.24e−01	8.92e−01	1.29e+00	1.70e+00	2.73e+00	3.70e+00
7	17	1.14e−02	3.29e−02	8.76e−02	2.18e−01	3.66e−01	5.18e−01	6.68e−01	1.02e+00	1.32e+00
7	19	9.17e−03	2.36e−02	5.39e−02	1.09e−01	1.56e−01	1.98e−01	2.36e−01	3.21e−01	3.95e−01
7	20	2.04e−02	5.49e−02	1.32e−01	3.01e−01	4.88e−01	6.85e−01	8.81e−01	1.34e+00	1.76e+00
7	23	1.45e−02	3.83e−02	8.85e−02	1.98e−01	3.22e−01	4.58e−01	6.00e−01	9.51e−01	1.28e+00
7	25	7.82e−03	2.42e−02	6.61e−02	1.59e−01	2.51e−01	3.37e−01	4.17e−01	5.93e−01	7.39e−01
7	27	1.47e−02	4.13e−02	1.21e−01	3.32e−01	5.52e−01	7.57e−01	9.41e−01	1.33e+00	1.63e+00
7	28	5.49e−03	1.44e−02	3.48e−02	7.32e−02	1.06e−01	1.34e−01	1.60e−01	2.14e−01	2.59e−01
7	33	9.10e−03	2.40e−02	6.24e−02	1.66e−01	2.88e−01	4.17e−01	5.44e−01	8.47e−01	1.12e+00
7	34	4.25e−03	1.36e−02	4.10e−02	1.15e−01	2.00e−01	2.87e−01	3.72e−01	5.68e−01	7.37e−01
7	36	1.96e−03	5.04e−03	1.26e−02	3.25e−02	5.69e−02	8.35e−02	1.11e−01	1.79e−01	2.43e−01
7	37	6.48e−04	2.70e−03	9.59e−03	2.92e−02	5.17e−02	7.46e−02	9.68e−02	1.48e−01	1.93e−01
8	9	2.53e−02	8.86e−02	3.13e−01	8.95e−01	1.47e+00	2.00e+00	2.50e+00	3.63e+00	4.65e+00
8	11	3.33e−02	8.51e−02	1.85e−01	3.49e−01	4.83e−01	5.99e−01	7.03e−01	9.29e−01	1.12e+00
8	12	1.41e−01	3.41e−01	7.29e−01	1.40e+00	1.99e+00	2.54e+00	3.07e+00	4.29e+00	5.38e+00
8	15	5.93e−02	1.49e−01	3.81e−01	9.28e−01	1.51e+00	2.11e+00	2.71e+00	4.17e+00	5.53e+00
8	17	2.35e−02	7.25e−02	1.97e−01	4.55e−01	6.93e−01	9.09e−01	1.11e+00	1.54e+00	1.92e+00
8	19	1.32e−02	3.31e−02	7.45e−02	1.48e−01	2.08e−01	2.60e−01	3.05e−01	4.02e−01	4.81e−01
8	20	3.22e−02	8.54e−02	1.97e−01	4.26e−01	6.71e−01	9.26e−01	1.18e+00	1.79e+00	2.34e+00
8	23	2.78e−02	7.33e−02	1.76e−01	4.12e−01	6.77e−01	9.54e−01	1.23e+00	1.90e+00	2.51e+00
8	25	1.75e−02	5.06e−02	1.25e−01	2.69e−01	3.97e−01	5.13e−01	6.18e−01	8.49e−01	1.05e+00
8	27	2.50e−02	7.39e−02	2.04e−01	5.07e−01	8.04e−01	1.08e+00	1.33e+00	1.86e+00	2.30e+00
8	28	7.32e−03	1.93e−02	4.81e−02	1.03e−01	1.48e−01	1.87e−01	2.20e−01	2.89e−01	3.44e−01
8	33	1.34e−02	4.36e−02	1.37e−01	3.87e−01	6.55e−01	9.18e−01	1.17e+00	1.74e+00	2.23e+00
8	34	6.57e−03	2.24e−02	6.98e−02	2.03e−01	3.55e−01	5.06e−01	6.50e−01	9.72e−01	1.25e+00
8	36	3.10e−03	8.81e−03	2.50e−02	7.54e−02	1.41e−01	2.14e−01	2.89e−01	4.67e−01	6.24e−01
8	37	9.05e−04	4.23e−03	1.61e−02	5.15e−02	9.49e−02	1.41e−01	1.87e−01	2.94e−01	3.88e−01
9	10	3.72e−02	9.04e−02	2.05e−01	3.98e−01	5.48e−01	6.76e−01	7.90e−01	1.04e+00	1.25e+00
9	11	1.28e−01	3.76e−01	1.15e+00	3.79e+00	7.97e+00	1.37e+01	2.11e+01	4.64e+01	8.16e+01
9	12	2.29e−01	6.34e−01	1.67e+00	4.52e+00	8.78e+00	1.51e+01	2.38e+01	5.82e+01	1.12e+02
9	13	1.66e−01	3.62e−01	7.36e−01	1.39e+00	1.95e+00	2.43e+00	2.85e+00	3.73e+00	4.44e+00
9	14	7.73e−02	1.91e−01	4.50e−01	9.54e−01	1.39e+00	1.77e+00	2.10e+00	2.78e+00	3.32e+00
9	15	1.12e−01	3.44e−01	1.05e+00	3.68e+00	8.16e+00	1.44e+01	2.23e+01	4.80e+01	8.03e+01
9	16	5.39e−02	1.36e−01	3.51e−01	8.65e−01	1.42e+00	1.98e+00	2.53e+00	3.80e+00	4.93e+00
9	17	7.63e−02	2.56e−01	7.88e−01	2.30e+00	4.33e+00	6.86e+00	9.85e+00	1.92e+01	3.11e+01
9	18	1.10e−02	3.43e−02	8.36e−02	1.70e−01	2.41e−01	3.02e−01	3.56e−01	4.70e−01	5.61e−01
9	19	2.75e−02	7.55e−02	1.81e−01	4.16e−01	6.92e−01	1.03e+00	1.44e+00	2.85e+00	4.83e+00
9	20	8.88e−02	2.36e−01	5.52e−01	1.23e+00	2.10e+00	3.22e+00	4.60e+00	9.08e+00	1.47e+01
9	21	4.20e−02	1.04e−01	2.26e−01	4.51e−01	6.63e−01	8.64e−01	1.05e+00	1.47e+00	1.82e+00
9	22	2.39e−02	6.18e−02	1.33e−01	2.53e−01	3.63e−01	4.66e−01	5.65e−01	7.92e−01	9.89e−01
9	23	5.36e−02	1.54e−01	4.24e−01	1.25e+00	2.57e+00	3.70e+00	5.17e+00	9.28e+00	1.37e+01
9	24	2.31e−02	6.48e−02	1.55e−01	3.45e−01	5.46e−01	7.52e−01	9.55e−01	1.43e+00	1.85e+00
9	25	3.65e−02	1.07e−01	2.74e−01	6.52e−01	1.14e+00	1.75e+00	2.51e+00	4.94e+00	7.98e+00
9	26	1.07e−02	3.01e−02	6.96e−02	1.36e−01	1.87e−01	2.26e−01	2.59e−01	3.23e−01	3.70e−01
9	27	3.43e−02	1.05e−01	3.20e−01	9.28e−01	1.69e+00	2.56e+00	3.51e+00	6.09e+00	8.85e+00
9	28	1.40e−02	4.14e−02	1.17e−01	2.92e−01	4.79e−01	6.89e−01	9.30e−01	1.69e+00	2.66e+00
9	29	5.96e−06	3.55e−05	2.11e−04	1.34e−03	3.91e−03	7.97e−03	1.34e−02	3.16e−02	5.51e−02

Table 2. Continued.

Level index		Temperature [K]								
i	j	500	1000	2000	4000	6000	8000	10000	15000	20000
9	30	1.64e−02	5.12e−02	1.47e−01	3.67e−01	5.83e−01	7.84e−01	9.68e−01	1.36e+00	1.67e+00
9	31	1.19e−02	3.47e−02	9.80e−02	2.54e−01	4.16e−01	5.71e−01	7.13e−01	1.02e+00	1.27e+00
9	32	1.51e−02	4.58e−02	1.29e−01	3.26e−01	5.21e−01	7.01e−01	8.64e−01	1.21e+00	1.48e+00
9	33	2.10e−02	7.05e−02	2.45e−01	8.33e−01	1.64e+00	2.57e+00	3.58e+00	6.28e+00	9.10e+00
9	34	1.15e−02	4.03e−02	1.64e−01	6.82e−01	1.49e+00	2.50e+00	3.64e+00	6.86e+00	1.03e+01
9	35	3.47e−03	9.55e−03	2.40e−02	5.99e−02	9.91e−02	1.38e−01	1.74e−01	2.54e−01	3.22e−01
9	36	4.52e−03	1.33e−02	4.01e−02	1.37e−01	2.94e−01	5.05e−01	7.64e−01	1.58e+00	2.59e+00
9	37	5.22e−04	2.24e−03	8.77e−03	3.37e−02	7.48e−02	1.32e−01	2.05e−01	4.48e−01	7.65e−01
10	11	2.78e−02	7.51e−02	1.67e−01	3.35e−01	4.85e−01	6.24e−01	7.52e−01	1.04e+00	1.29e+00
10	12	1.38e−01	3.24e−01	6.56e−01	1.14e+00	1.50e+00	1.80e+00	2.06e+00	2.60e+00	3.02e+00
10	15	6.46e−02	1.66e−01	4.03e−01	8.81e−01	1.31e+00	1.69e+00	2.04e+00	2.74e+00	3.30e+00
10	17	1.90e−02	5.80e−02	1.52e−01	3.32e−01	4.91e−01	6.33e−01	7.62e−01	1.03e+00	1.25e+00
10	19	9.00e−03	2.35e−02	5.41e−02	1.09e−01	1.56e−01	1.96e−01	2.30e−01	3.00e−01	3.58e−01
10	20	2.93e−02	6.96e−02	1.49e−01	2.86e−01	4.04e−01	5.09e−01	6.04e−01	8.02e−01	9.59e−01
10	23	3.37e−02	7.88e−02	1.61e−01	3.01e−01	4.23e−01	5.33e−01	6.33e−01	8.45e−01	1.01e+00
10	25	1.19e−02	3.44e−02	8.50e−02	1.72e−01	2.40e−01	2.97e−01	3.47e−01	4.48e−01	5.28e−01
10	27	1.77e−02	4.66e−02	1.11e−01	2.30e−01	3.26e−01	4.05e−01	4.72e−01	6.04e−01	7.02e−01
10	28	4.56e−03	1.27e−02	2.84e−02	5.42e−02	7.45e−02	9.16e−02	1.07e−01	1.40e−01	1.70e−01
10	33	1.29e−02	3.67e−02	9.07e−02	2.01e−01	3.04e−01	3.96e−01	4.78e−01	6.48e−01	7.77e−01
10	34	6.35e−03	1.82e−02	4.54e−02	1.03e−01	1.60e−01	2.13e−01	2.63e−01	3.72e−01	4.62e−01
10	36	2.06e−03	5.48e−03	1.29e−02	2.94e−02	4.83e−02	6.97e−02	9.30e−02	1.56e−01	2.18e−01
10	37	5.40e−04	2.14e−03	7.17e−03	2.04e−02	3.38e−02	4.60e−02	5.67e−02	7.78e−02	9.34e−02
11	12	1.66e−01	4.86e−01	1.29e+00	3.23e+00	5.60e+00	8.53e+00	1.21e+01	2.43e+01	4.12e+01
11	13	9.06e−02	2.01e−01	4.32e−01	8.54e−01	1.22e+00	1.53e+00	1.81e+00	2.40e+00	2.85e+00
11	14	5.07e−02	1.14e−01	2.26e−01	4.16e−01	5.86e−01	7.43e−01	8.88e−01	1.20e+00	1.46e+00
11	15	6.71e−02	1.98e−01	6.38e−01	2.04e+00	3.97e+00	6.32e+00	9.04e+00	1.72e+01	2.69e+01
11	16	2.42e−02	9.04e−02	2.86e−01	6.96e−01	1.06e+00	1.37e+00	1.65e+00	2.23e+00	2.68e+00
11	17	8.66e−02	3.69e−01	1.49e+00	6.63e+00	1.63e+01	3.08e+01	5.02e+01	1.21e+02	2.23e+02
11	18	7.39e−03	2.13e−02	5.09e−02	1.01e−01	1.42e−01	1.78e−01	2.09e−01	2.77e−01	3.37e−01
11	19	3.18e−02	9.19e−02	2.09e−01	4.38e−01	6.93e−01	1.01e+00	1.42e+00	3.01e+00	5.54e+00
11	20	1.14e−01	3.60e−01	9.79e−01	2.50e+00	4.67e+00	7.78e+00	1.19e+01	2.62e+01	4.55e+01
11	21	3.63e−02	9.53e−02	2.03e−01	3.65e−01	4.91e−01	5.99e−01	6.94e−01	8.90e−01	1.04e+00
11	22	2.54e−02	5.98e−02	1.16e−01	1.97e−01	2.63e−01	3.21e−01	3.74e−01	4.89e−01	5.87e−01
11	23	5.62e−02	1.89e−01	6.29e−01	2.41e+00	5.31e+00	9.01e+00	1.33e+01	2.54e+01	3.84e+01
11	24	2.55e−02	6.97e−02	1.65e−01	3.35e−01	4.79e−01	6.04e−01	7.14e−01	9.38e−01	1.11e+00
11	25	3.16e−02	9.94e−02	2.73e−01	6.74e−01	1.19e+00	1.89e+00	2.81e+00	6.15e+00	1.09e+01
11	26	4.10e−03	1.28e−02	3.24e−02	6.49e−02	8.92e−02	1.08e−01	1.25e−01	1.58e−01	1.86e−01
11	27	3.15e−02	1.03e−01	2.81e−01	7.49e−01	1.40e+00	2.23e+00	3.24e+00	6.33e+00	1.01e+01
11	28	1.69e−02	5.10e−02	1.57e−01	4.28e−01	7.26e−01	1.05e+00	1.43e+00	2.58e+00	4.05e+00
11	29	3.45e−06	2.20e−05	1.43e−04	1.05e−03	3.33e−03	7.17e−03	1.24e−02	3.07e−02	5.41e−02
11	30	1.19e−02	3.42e−02	9.34e−02	2.17e−01	3.28e−01	4.25e−01	5.10e−01	6.81e−01	8.09e−01
11	31	7.28e−03	1.97e−02	4.89e−02	1.14e−01	1.80e−01	2.44e−01	3.05e−01	4.39e−01	5.50e−01
11	32	9.88e−03	3.02e−02	8.29e−02	1.98e−01	3.02e−01	3.92e−01	4.70e−01	6.24e−01	7.37e−01
11	33	2.71e−02	1.09e−01	3.92e−01	1.28e+00	2.44e+00	3.77e+00	5.19e+00	8.98e+00	1.29e+01
11	34	1.15e−02	5.23e−02	2.21e−01	8.73e−01	1.90e+00	3.24e+00	4.80e+00	9.41e+00	1.46e+01
11	35	1.88e−03	5.00e−03	1.19e−02	2.73e−02	4.53e−02	6.51e−02	8.59e−02	1.39e−01	1.91e−01
11	36	3.83e−03	1.32e−02	4.34e−02	1.39e−01	2.70e−01	4.30e−01	6.17e−01	1.20e+00	1.93e+00
11	37	6.06e−04	2.10e−03	6.28e−03	1.72e−02	3.28e−02	5.41e−02	8.10e−02	1.69e−01	2.78e−01
12	13	3.03e−01	7.41e−01	1.74e+00	3.65e+00	5.33e+00	6.82e+00	8.15e+00	1.09e+01	1.32e+01
12	14	1.29e−01	3.78e−01	1.02e+00	2.34e+00	3.50e+00	4.50e+00	5.36e+00	7.08e+00	8.39e+00
12	15	2.24e−01	1.03e+00	5.60e+00	3.08e+01	7.87e+01	1.48e+02	2.38e+02	5.39e+02	9.36e+02
12	16	1.03e−01	3.03e−01	8.47e−01	2.14e+00	3.51e+00	4.88e+00	6.19e+00	9.16e+00	1.17e+01
12	17	1.37e−01	6.24e−01	2.63e+00	1.12e+01	2.63e+01	4.80e+01	7.61e+01	1.73e+02	3.04e+02
12	18	2.53e−02	7.55e−02	1.86e−01	3.98e−01	5.80e−01	7.36e−01	8.71e−01	1.14e+00	1.34e+00
12	19	1.38e−01	3.76e−01	1.00e+00	2.77e+00	5.06e+00	7.77e+00	1.08e+01	1.97e+01	2.99e+01
12	20	2.73e−01	7.84e−01	1.98e+00	4.99e+00	9.29e+00	1.51e+01	2.25e+01	4.73e+01	7.95e+01
12	21	9.32e−02	2.52e−01	5.83e−01	1.19e+00	1.71e+00	2.17e+00	2.59e+00	3.46e+00	4.17e+00
12	22	6.65e−02	1.73e−01	3.76e−01	7.24e−01	1.02e+00	1.29e+00	1.53e+00	2.08e+00	2.54e+00
12	23	1.56e−01	4.62e−01	1.37e+00	4.40e+00	8.85e+00	1.44e+01	2.09e+01	3.97e+01	6.13e+01
12	24	7.48e−02	2.10e−01	4.97e−01	1.05e+00	1.58e+00	2.07e+00	2.54e+00	3.55e+00	4.38e+00
12	25	1.40e−01	3.93e−01	9.96e−01	2.42e+00	4.17e+00	6.29e+00	8.76e+00	1.63e+01	2.54e+01
12	26	1.91e−02	5.41e−02	1.33e−01	2.72e−01	3.81e−01	4.69e−01	5.43e−01	6.86e−01	7.90e−01
12	27	1.34e−01	4.08e−01	1.27e+00	3.80e+00	6.92e+00	1.04e+01	1.40e+01	2.38e+01	3.43e+01
12	28	4.70e−02	1.25e−01	3.28e−01	8.64e−01	1.52e+00	2.30e+00	3.18e+00	5.75e+00	8.64e+00
12	29	1.58e−05	9.00e−05	5.75e−04	3.81e−03	1.08e−02	2.17e−02	3.65e−02	8.69e−02	1.51e−01
12	30	4.26e−02	1.26e−01	3.47e−01	8.38e−01	1.30e+00	1.72e+00	2.10e+00	2.88e+00	3.51e+00
12	31	3.49e−02	9.35e−02	2.39e−01	5.71e−01	8.92e−01	1.19e+00	1.47e+00	2.08e+00	2.59e+00
12	32	3.73e−02	1.15e−01	3.23e−01	7.87e−01	1.23e+00	1.62e+00	1.97e+00	2.69e+00	3.24e+00
12	33	9.04e−02	3.07e−01	1.03e+00	3.33e+00	6.44e+00	1.01e+01	1.42e+01	2.54e+01	3.75e+01
12	34	3.47e−02	1.26e−01	4.52e−01	1.57e+00	3.18e+00	5.13e+00	7.34e+00	1.37e+01	2.08e+01
12	35	8.20e−03	2.04e−02	4.78e−02	1.18e−01	2.00e−01	2.85e−01	3.69e−01	5.67e−01	7.43e−01
12	36	1.14e−02	3.76e−02	1.46e−01	6.11e−01	1.34e+00	2.26e+00	3.31e+00	6.31e+00	9.61e+00
12	37	8.76e−04	3.68e−03	1.43e−02	4.96e−02	9.48e−02	1.46e−01	2.02e−01	3.58e−01	5.34e−01

Table 2. Continued.

Level index		Temperature [K]								
i	*j*	500	1000	2000	4000	6000	8000	10000	15000	20000
13	15	1.71e−01	4.97e−01	1.35e+00	3.22e+00	5.04e+00	6.75e+00	8.32e+00	1.17e+01	1.44e+01
13	17	1.29e−01	3.40e−01	8.53e−01	1.86e+00	2.76e+00	3.54e+00	4.24e+00	5.67e+00	6.77e+00
13	19	4.08e−02	1.05e−01	2.44e−01	4.98e−01	7.12e−01	8.92e−01	1.05e+00	1.35e+00	1.58e+00
13	20	1.39e−01	3.51e−01	7.80e−01	1.56e+00	2.28e+00	2.93e+00	3.54e+00	4.84e+00	5.91e+00
13	23	1.57e−01	3.85e−01	8.36e−01	1.66e+00	2.40e+00	3.07e+00	3.66e+00	4.91e+00	5.89e+00
13	25	6.47e−02	1.75e−01	4.15e−01	8.48e−01	1.21e+00	1.53e+00	1.80e+00	2.37e+00	2.81e+00
13	27	5.77e−02	1.58e−01	4.04e−01	9.29e−01	1.42e+00	1.85e+00	2.24e+00	3.03e+00	3.64e+00
13	28	2.21e−02	6.05e−02	1.35e−01	2.59e−01	3.60e−01	4.45e−01	5.18e−01	6.64e−01	7.74e−01
13	33	4.96e−02	1.44e−01	3.84e−01	9.20e−01	1.44e+00	1.91e+00	2.33e+00	3.23e+00	3.94e+00
13	34	2.49e−02	8.19e−02	2.27e−01	5.47e−01	8.57e−01	1.15e+00	1.41e+00	1.97e+00	2.42e+00
13	36	8.59e−03	2.24e−02	5.27e−02	1.26e−01	2.10e−01	2.99e−01	3.87e−01	5.95e−01	7.80e−01
13	37	2.91e−03	1.26e−02	4.55e−02	1.31e−01	2.15e−01	2.91e−01	3.58e−01	4.91e−01	5.90e−01
14	15	6.88e−02	2.04e−01	5.68e−01	1.40e+00	2.23e+00	3.02e+00	3.76e+00	5.34e+00	6.62e+00
14	17	4.80e−02	1.29e−01	3.16e−01	6.82e−01	1.05e+00	1.42e+00	1.79e+00	2.64e+00	3.39e+00
14	19	2.18e−02	5.46e−02	1.21e−01	2.40e−01	3.45e−01	4.42e−01	5.34e−01	7.38e−01	9.12e−01
14	20	7.73e−02	1.99e−01	4.42e−01	8.86e−01	1.29e+00	1.67e+00	2.01e+00	2.73e+00	3.30e+00
14	23	6.50e−02	1.83e−01	4.52e−01	9.83e−01	1.48e+00	1.92e+00	2.33e+00	3.17e+00	3.83e+00
14	25	2.99e−02	8.21e−02	1.92e−01	3.94e−01	5.71e−01	7.29e−01	8.74e−01	1.19e+00	1.46e+00
14	27	3.38e−02	9.54e−02	2.42e−01	5.45e−01	8.28e−01	1.08e+00	1.31e+00	1.78e+00	2.13e+00
14	28	1.21e−02	2.92e−02	6.51e−02	1.32e−01	1.92e−01	2.44e−01	2.92e−01	3.93e−01	4.76e−01
14	33	3.02e−02	8.52e−02	2.17e−01	4.96e−01	7.65e−01	1.01e+00	1.24e+00	1.71e+00	2.08e+00
14	34	1.56e−02	4.49e−02	1.19e−01	2.89e−01	4.57e−01	6.17e−01	7.68e−01	1.11e+00	1.41e+00
14	36	4.58e−03	1.38e−02	3.81e−02	9.49e−02	1.57e−01	2.21e−01	2.86e−01	4.45e−01	5.90e−01
14	37	3.69e−03	1.41e−02	4.32e−02	1.05e−01	1.58e−01	2.02e−01	2.37e−01	3.06e−01	3.55e−01
15	16	1.21e−01	4.23e−01	1.23e+00	2.96e+00	4.70e+00	6.45e+00	8.18e+00	1.23e+01	1.61e+01
15	17	5.59e−01	1.65e+00	4.40e+00	1.13e+01	2.00e+01	3.06e+01	4.32e+01	8.55e+01	1.48e+02
15	18	3.91e−02	1.13e−01	2.54e−01	4.74e−01	6.43e−01	7.84e−01	9.05e−01	1.15e+00	1.34e+00
15	19	1.58e−01	4.01e−01	9.20e−01	2.13e+00	3.61e+00	5.31e+00	7.20e+00	1.25e+01	1.83e+01
15	20	4.14e−01	1.19e+00	3.20e+00	9.53e+00	1.95e+01	3.32e+01	5.04e+01	1.07e+02	1.82e+02
15	21	1.50e−01	3.63e−01	7.71e−01	1.47e+00	2.07e+00	2.61e+00	3.11e+00	4.23e+00	5.21e+00
15	22	1.10e−01	2.78e−01	5.85e−01	1.06e+00	1.44e+00	1.79e+00	2.11e+00	2.83e+00	3.43e+00
15	23	1.91e−01	5.87e−01	1.73e+00	5.42e+00	1.10e+01	1.87e+01	2.84e+01	6.13e+01	1.05e+02
15	24	1.51e−01	3.55e−01	7.42e−01	1.43e+00	2.07e+00	2.69e+00	3.28e+00	4.67e+00	5.91e+00
15	25	1.75e−01	5.16e−01	1.35e+00	3.42e+00	5.95e+00	8.86e+00	1.21e+01	2.12e+01	3.12e+01
15	26	3.34e−02	8.43e−02	1.80e−01	3.28e−01	4.38e−01	5.27e−01	6.03e−01	7.52e−01	8.67e−01
15	27	1.78e−01	5.45e−01	1.59e+00	4.68e+00	8.83e+00	1.37e+01	1.90e+01	3.35e+01	4.89e+01
15	28	7.03e−02	1.99e−01	5.01e−01	1.15e+00	1.85e+00	2.61e+00	3.39e+00	5.39e+00	7.34e+00
15	29	3.23e−06	2.35e−05	1.38e−04	7.75e−04	2.24e−03	4.60e−03	7.73e−03	1.77e−02	2.91e−02
15	30	4.89e−02	1.43e−01	4.02e−01	1.00e+00	1.60e+00	2.17e+00	2.71e+00	3.89e+00	4.88e+00
15	31	3.48e−02	9.97e−02	2.67e−01	6.51e−01	1.05e+00	1.45e+00	1.84e+00	2.71e+00	3.43e+00
15	32	5.55e−02	1.52e−01	3.92e−01	9.24e−01	1.44e+00	1.91e+00	2.34e+00	3.28e+00	4.05e+00
15	33	1.16e−01	4.02e−01	1.27e+00	3.84e+00	7.46e+00	1.21e+01	1.78e+01	3.58e+01	5.82e+01
15	34	6.66e−02	2.53e−01	8.83e−01	2.77e+00	5.12e+00	7.71e+00	1.05e+01	1.79e+01	2.58e+01
15	35	9.74e−03	2.71e−02	7.63e−02	2.21e−01	3.85e−01	5.46e−01	6.98e−01	1.03e+00	1.32e+00
15	36	1.96e−02	7.53e−02	3.25e−01	1.26e+00	2.53e+00	4.04e+00	5.73e+00	1.06e+01	1.59e+01
15	37	3.71e−03	1.74e−02	6.28e−02	1.73e−01	2.82e−01	3.85e−01	4.82e−01	7.05e−01	9.08e−01
16	17	6.39e−02	2.12e−01	6.15e−01	1.46e+00	2.23e+00	2.93e+00	3.55e+00	4.86e+00	5.90e+00
16	19	3.93e−02	1.05e−01	2.45e−01	4.87e−01	6.80e−01	8.43e−01	9.84e−01	1.27e+00	1.50e+00
16	20	1.66e−01	4.26e−01	9.54e−01	1.86e+00	2.63e+00	3.31e+00	3.93e+00	5.30e+00	6.47e+00
16	23	1.53e−01	3.68e−01	8.15e−01	1.65e+00	2.42e+00	3.16e+00	3.85e+00	5.45e+00	6.86e+00
16	25	7.57e−02	2.09e−01	4.90e−01	9.57e−01	1.33e+00	1.65e+00	1.94e+00	2.54e+00	3.03e+00
16	27	7.05e−02	2.07e−01	5.46e−01	1.26e+00	1.94e+00	2.57e+00	3.15e+00	4.40e+00	5.41e+00
16	28	2.73e−02	6.95e−02	1.55e−01	3.03e−01	4.21e−01	5.19e−01	6.03e−01	7.73e−01	9.04e−01
16	33	7.84e−02	2.09e−01	5.09e−01	1.17e+00	1.83e+00	2.46e+00	3.07e+00	4.44e+00	5.62e+00
16	34	3.25e−02	1.01e−01	2.73e−01	6.78e−01	1.11e+00	1.54e+00	1.95e+00	2.84e+00	3.56e+00
16	36	8.10e−03	2.43e−02	7.04e−02	2.09e−01	3.76e−01	5.50e−01	7.23e−01	1.12e+00	1.48e+00
16	37	6.15e−03	2.99e−02	1.11e−01	3.00e−01	4.74e−01	6.25e−01	7.54e−01	1.01e+00	1.19e+00
17	18	1.77e−02	5.49e−02	1.40e−01	2.94e−01	4.29e−01	5.50e−01	6.60e−01	8.94e−01	1.08e+00
17	19	1.36e−01	5.67e−01	2.27e+00	9.74e+00	2.33e+01	4.30e+01	6.89e+01	1.60e+02	2.87e+02
17	20	3.48e−01	1.19e+00	3.93e+00	1.39e+01	3.19e+01	6.02e+01	9.99e+01	2.53e+02	4.84e+02
17	21	1.34e−01	3.42e−01	7.31e−01	1.32e+00	1.76e+00	2.10e+00	2.38e+00	2.93e+00	3.33e+00
17	22	7.91e−02	2.03e−01	4.27e−01	7.75e−01	1.05e+00	1.28e+00	1.48e+00	1.90e+00	2.23e+00
17	23	2.92e−01	1.04e+00	3.55e+00	1.35e+01	3.03e+01	5.32e+01	8.12e+01	1.69e+02	2.75e+02
17	24	1.14e−01	2.99e−01	6.57e−01	1.26e+00	1.77e+00	2.21e+00	2.60e+00	3.37e+00	3.95e+00
17	25	1.87e−01	6.64e−01	2.05e+00	6.11e+00	1.19e+01	1.94e+01	2.88e+01	5.90e+01	9.77e+01
17	26	2.12e−02	6.11e−02	1.42e−01	2.67e−01	3.58e−01	4.29e−01	4.87e−01	5.98e−01	6.79e−01
17	27	1.31e−01	4.62e−01	1.52e+00	4.70e+00	8.93e+00	1.40e+01	1.97e+01	3.64e+01	5.58e+01
17	28	4.91e−02	1.62e−01	4.85e−01	1.38e+00	2.50e+00	3.88e+00	5.58e+00	1.13e+01	1.92e+01
17	29	3.10e−06	1.66e−05	9.34e−05	6.09e−04	1.64e−03	3.11e−03	4.95e−03	1.09e−02	1.84e−02
17	30	3.81e−02	1.05e−01	2.71e−01	6.07e−01	9.02e−01	1.16e+00	1.37e+00	1.80e+00	2.12e+00
17	31	2.29e−02	6.50e−02	1.64e−01	3.72e−01	5.71e−01	7.55e−01	9.23e−01	1.29e+00	1.58e+00
17	32	3.29e−02	9.61e−02	2.50e−01	5.78e−01	8.83e−01	1.15e+00	1.38e+00	1.84e+00	2.18e+00
17	33	1.02e−01	4.17e−01	1.64e+00	5.79e+00	1.15e+01	1.81e+01	2.54e+01	4.53e+01	6.64e+01

Table 2. Continued.

Level index		Temperature [K]								
i	*j*	500	1000	2000	4000	6000	8000	10000	15000	20000
17	34	4.22e−02	1.85e−01	8.22e−01	3.38e+00	7.34e+00	1.24e+01	1.82e+01	3.55e+01	5.51e+01
17	35	8.38e−03	2.18e−02	5.03e−02	1.17e−01	1.88e−01	2.60e−01	3.28e−01	4.80e−01	6.06e−01
17	36	1.15e−02	4.83e−02	1.75e−01	6.24e−01	1.36e+00	2.37e+00	3.63e+00	7.74e+00	1.30e+01
17	37	1.77e−03	6.31e−03	1.87e−02	4.91e−02	8.50e−02	1.28e−01	1.79e−01	3.41e−01	5.50e−01